SOIL BUILDING WITH LEGUMES

RESULTS FROM ILLINOIS SOIL EXPERIMENT FIELDS

By H. J. SNIDER

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SOIL BUILDING WITH LEGUMES

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LEGUMES ARE RECOGNIZED more and more as the key to a good soil-improvement program. They furnish generous supplies of organic matter and nitrogen. Their use enables other crops in the rotation to make better yields. And they form a cover which protects the soil against destructive erosion.

Legumes can be grown abundantly and profitably on almost every acre of farm land in Illinois. They have been grown for many years on the Illinois soil-experiment fields. Some of the differences that have resulted from these years of experiment with legumes, particularly with alfalfa, sweet clover, red clover, and soybeans, are discussed in this publication.

Legumes Add Organic Matter and Build Up Nitrogen

Organic matter is the life of the soil. A good supply of it is necessary if the soil is to have good tilth. It keeps the soil loose and mellow so that air can get in, and it makes the soil very easy to cultivate. It also enables the soil to take up and hold water.

When organic matter is depleted, the soil becomes compact and loses whatever dark color it may have had. Where there is an abundant supply of organic matter, crops benefit to the fullest extent from limestone, rock phosphate, and other mineral fertilizers. Organic matter is almost the entire source of soil nitrogen.

Corn yields are usually highest on land that contains relatively large amounts of nitrogen and organic matter. This is brought out by comparing six untreated experiment fields on dark-colored soil with six on light-colored soil (Table 1). The topsoil of the six on light-colored soil contained only 1,300 to 2,600 pounds of nitrogen and 8 to 22 tons of organic matter an acre, and corn yields were only 6 to 14 bushels. The other fields had over 3,000 pounds of nitrogen and over 30 tons of organic matter an acre in the topsoil and averaged 44 to 50 bushels of

Table 1. — Organic Matter, Nitrogen, and Corn Yields on Untreated Soils of Twelve Experiment Fields[a]

Experiment field	Organic matter per acre	Total nitrogen per acre	Corn per acre
Dark-colored soils			
	tons	*lb.*	*bu.*
Aledo	46.9	4 320	50
Bloomington	46.5	4 560	50
Dixon	37.1	3 750	44
Carthage	34.1	3 210	50
Clayton	33.0	3 170	47
Mount Morris	30.3	3 480	50
Average	38.0	3 750	48
Light-colored soils			
Oblong	22.0	2 630	14
Newton	18.2	2 130	6
Ewing	16.5	2 030	11
Raleigh	16.2	1 930	11
Enfield	12.7	1 500	10
Elizabethtown	7.9	1 320	11
Average	15.6	1 920	10

[a] Corn yields are averages of four years. Data for organic matter and nitrogen represent amounts after fields had been in operation about twenty-five years.

corn. Nitrogen and organic matter cannot, of course, be given all the credit for high yields, but they are largely responsible for a soil condition that leads to high productivity.

How can an adequate supply of organic matter be kept in soil? Mainly, by growing legumes often and turning them back into the soil. A satisfactory rotation for every farm should include legumes on a quarter to a half of the cropland every year. Even on productive land legumes should be grown at least once every three or four years.

On the Morrow plots at Urbana, three cropping systems have been followed since 1876: corn-oats-clover, corn-oats, and continuous corn. In 1943 nitrogen and organic matter were higher where red clover has been included in the rotation than where it was not used, both on treated and untreated land (Table 2). Where the rotation has included both red clover and manure, the

level of organic matter was highest — probably not much less than it was when the land was broken out of the original prairie.

The more-productive dark soils in Illinois gain more in nitrogen and organic matter from legumes and crop residues than the light soils do, according to twenty-five-year records from several experiment fields. At the end of twenty-five years dark soils which had an RLrPK treatment (residues, limestone, rock phosphate, muriate of potash) averaged 580 more pounds of nitrogen

Table 2. — Composition of Soils on the Morrow Plots, Urbana, 1943
(Amounts are per acre)

Soil treatment	Total organic matter	Total nitrogen	Soluble phos-phorus	Available potas-sium	Available calcium	Available magne-sium
Corn-oats rotation						
	tons	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*
None	36.2	3 300	14	210	3 390	700
MLrP[a]	39.7	4 100	1 220	310	5 570	840
Corn-oats-clover rotation						
None	38.4	3 600	14	230	2 890	670
MLrP[a]	47.8	4 500	1 280	330	6 310	1 030

[a] Manure, limestone, rock phosphate.

an acre and 6.7 more tons of organic matter than the untreated dark soils (Table 3). On the light and yellow soils under similar cropping systems, the same treatment resulted in a gain of 390 pounds of nitrogen and 4 tons of organic matter.

In emphasizing the importance of legumes as a source of organic matter, we should not forget manure. For centuries farmers have justifiably placed great emphasis on its use to keep their soils productive. Its value for soil improvement is based largely on the organic matter which it adds to the soil. Where livestock are kept, manure becomes, along with legumes, an important part of the soil-building program. On the Illinois soil-experiment fields it has proved as effective as legumes in increasing crop yields.

Table 3. — Organic Matter and Nitrogen[a] in Both Treated and Untreated Soils on Twelve Experiment Fields

(Amounts are per acre)

Experiment field	On untreated soil		On treated (RLrPK[b]) soil		Gain from treatment	
	Organic matter	Total nitrogen	Organic matter	Total nitrogen	Organic matter	Total nitrogen
Dark-colored soils						
	tons	*lb.*	*tons*	*lb.*	*tons*	*lb.*
Aledo	46.9	4 320	61.7	5 240	14.8	920
Bloomington	46.5	4 560	57.6	5 360	11.1	800
Dixon	37.1	3 750	38.0	3 980	.9	230
Carthage	34.1	3 210	40.0	3 820	5.9	610
Clayton	33.0	3 170	36.4	3 620	3.4	450
Mount Morris	30.3	3 480	34.3	3 920	4.0	440
Average	38.0	3 750	44.7	4 320	6.7	580
Light-colored soils						
Oblong	22.0	2 630	25.8	2 850	3.8	220
Newton	18.2	2 130	19.7	2 310	1.5	180
Ewing	16.5	2 030	20.8	2 440	4.3	410
Raleigh	16.2	1 930	21.1	2 380	4.9	450
Enfield	12.7	1 500	18.5	2 230	5.8	730
Elizabethtown	7.9	1 320	11.7	1 660	3.8	340
Average	15.6	1 920	19.6	2 310	4.0	390

[a] Organic matter and nitrogen represent amounts after fields had been in operation about twenty-five years.
[b] Crop residues, limestone, rock phosphate, muriate of potash.

Legumes Increase Yields of Other Crops

One way to measure the work legumes do in building up the soil is to see what effect they have on the yields of other crops in the rotation. Tests on the Morrow plots show that red clover in the rotation resulted in higher yields of corn and oats and increased the protein in the corn and oat grain (Table 4). At the same time the organic matter and nitrogen in the soil were maintained at a considerably higher level than where legumes were not grown.

In a corn-oats-clover rotation with MLrP treatment (manure, limestone, rock phosphate), corn yielded 101 bushels an acre in 1943 and contained 11.4 percent protein, which is equal to 638 pounds of protein in 100 bushels of grain. In a corn-oats

rotation without soil treatment or clover, the corn yielded only 22 bushels an acre and contained only 7.8 percent protein, which is equal to 437 pounds of protein in 100 bushels of grain, a reduction of 79 bushels of grain an acre and 201 pounds of protein in 100 bushels of grain where there was neither clover nor treatment. On untreated land with a corn-oats-clover rotation, the corn yield was 46 bushels and the grain contained 526 pounds of protein in 100 bushels. Thus the red clover was responsible for 24 more bushels of corn an acre and 89 more pounds of protein in 100 bushels of grain.

For oats also the use of red clover in the rotation resulted in higher yields and a higher percentage of protein. On the treated land (MLrP) of the corn-oats-clover rotation, the oat yield in 1944 was 72 bushels an acre and the protein content was 235 pounds in 50 bushels. On the treated land of the corn-oats rotation, the oat yield was 54 bushels an acre and the protein content was 222 pounds in 50 bushels. Thus where there was no clover in the rotation, the oat yield was 18 bushels to the acre less than where clover was included, and the protein in 50 bushels of grain was 13 pounds less. Oats on the untreated land in the corn-oats-clover rotation yielded 53 bushels an acre and contained 214 pounds of protein in 50 bushels of grain; in the corn-oats rota-

Table 4. — Yield and Protein Content of Corn, Oats, and Red Clover From the Morrow Plots[a]

Soil treatment	Corn		Oats		Red clover	
	Grain per acre	Protein	Grain per acre	Protein	Hay per acre	Protein
Corn-oats rotation						
	bu.	*perct.*	*bu.*	*perct.*	*lb.*	*perct.*
None	22	7.8	30	12.1	.....	....
MLrP[b]	83	10.2	54	13.9	.....	....
Corn-oats-clover rotation						
None	46	9.4	53	13.4	3 260	16.5
MLrP[b]	101	11.4	72	14.7	6 940	15.3

[a] Corn, 1943; oats, 1944; clover, two cuttings in 1945.
[b] Manure, limestone, rock phosphate.

tion they yielded only 30 bushels and contained only 194 pounds of protein in each 50 bushels, a difference of 23 bushels of grain an acre and 20 pounds of protein in 50 bushels in favor of clover in the rotation.

	None	RLrPK	MLrP	ML	M	None
	(Pounds per acre from different treatments)					
Hay.........	930	3,920	4,440	2,560	2,020	1,560
Nitrogen....	14	79	116	60	52	39

	RL	RLrP	RL	RLrP	RLrPK
	(Pounds per acre from different treatments)				
Hay..........	3,780	4,860	1,780	2,220	3,300
Nitrogen.....	103	128	44	53	75

Soil treatment made the difference in these bundles of hay from four Illinois soil-experiment fields (each shows the growth from four square feet). Upper left, timothy-clover-alfalfa, south farm, Urbana, 1948; upper right, clover-alfalfa, Joliet, 1948; lower left, clover, Dixon, 1947; lower right, clover, Enfield, 1949. R = residues, M = manure, L = limestone, rP = rock phosphate, K = muriate of potash. (Fig. 1)

Legumes Need Soil Treatment for Best Growth

A great many people believe that all it takes to get a satisfactory crop of legumes is to lime the land. Just how wrong this idea is can be seen from Fig. 1. Most of the cropped lands in Illinois require limestone and phosphate, and frequently potash, in order to grow the best crops of legumes.

Where manure and limestone had been applied on the Joliet experiment field, a clover-alfalfa mixture in 1948 yielded 2,560 pounds of hay an acre containing 60 pounds of nitrogen. Where rock phosphate had been used in addition to manure and lime, the yields were 4,440 pounds of hay and 116 pounds of nitrogen — a gain of 1,880 pounds of hay and 56 pounds of nitrogen to be credited to the phosphate. At Enfield adding muriate of potash increased acre-yields of red clover by 1,080 pounds of hay and 22 pounds of nitrogen in 1949.

The first cutting of red clover on the treated (MLrP) part of the Morrow plots in 1948 yielded 6,370 pounds of hay an acre, and this hay contained 144 pounds of nitrogen. On the untreated land the yield was 890 pounds of hay and 24 pounds of nitrogen. Had both crops of clover been plowed under for soil improvement, the clover on the treated land would have added six times as much nitrogen and seven times as much organic matter as the clover on the untreated land.

Table 5. — Nitrogen in the Topsoil of Four Experiment Fields, 1916, 1935, and 1945

(Corn-oats-wheat-clover rotation)

Experiment field	Soil treatment	Pounds of nitrogen per acre			
		1916	1935	1945	Gain or loss in 29 years
Newton	None	2 960	2 580	2 300	−660
	RLrPK[a]	2 920	2 790	2 500	−420
Bloomington	None	5 240	4 600	4 480	−760
	RLrPK[a]	5 380	5 400	5 480	+100
Raleigh	None	2 130	1 940	1 980	−150
	RLrPK[a]	2 420	2 380	2 560	+140
Ewing	None	2 220	1 980	2 060	−160
	RLrPK[a]	2 490	2 440	2 460	− 30

[a] Crop residues, limestone, rock phosphate, muriate of potash.

Over a period of twenty-nine years at four Illinois experiment fields, legumes did not grow well and were not able to maintain the nitrogen content of the soil unless the soil was treated (Table 5). On the untreated plots of each field, the nitrogen in the soil was appreciably less at the end of the period than at the beginning, even though clover was seeded in a four-year rotation. The same rotation on treated soil (RLrPK) at Bloomington and Raleigh during the period resulted in a small gain in soil nitrogen; at Ewing there was practically no change. At Newton, where drainage is a problem, there was a large loss of soil nitrogen under the RLrPK treatment, but the loss was even greater where there was no treatment.

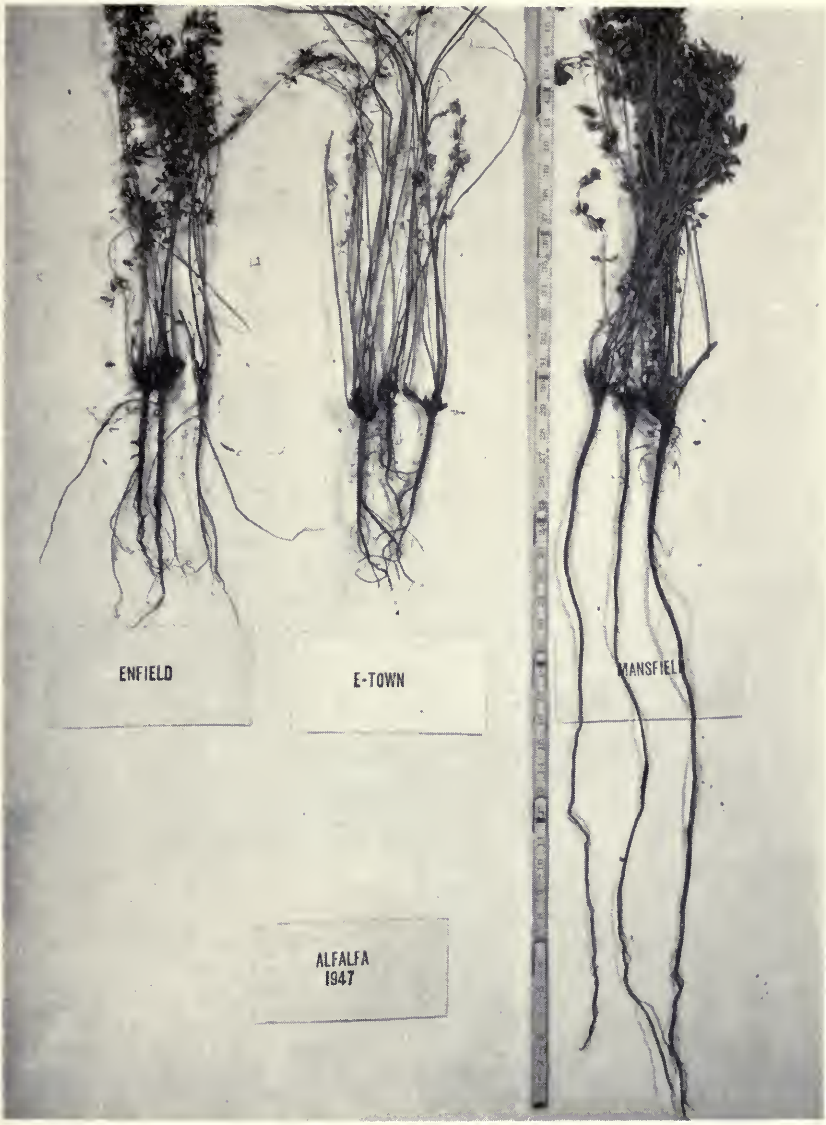
Legumes Differ in Ability to Improve Soils

On the Joliet field a mixture of red clover and alfalfa in the rotation proved to be superior to soybeans in improving both yield and quality of the corn crop (Table 6). Corn following a combination of red clover and alfalfa on treated land (RLrPK)

Table 6. — Yield and Protein Content of Corn Grain Following Soybeans and Following Clover-Alfalfa in the Rotation
(Joliet experiment field)

Year	Grain per acre following—		Protein in grain following—	
	Soybeans	Clover-alfalfa	Soybeans	Clover-alfalfa
No soil treatment				
	bu.	*bu.*	*perct.*	*perct.*
1946	32	39	10.4	10.0
1947	44	43	8.5	9.6
1948	51	63	8.9	10.1
1949	36	41	9.8	10.8
Average	41	47	9.4	10.1
RLrPK[a] treatment				
1946	74	81	8.9	10.8
1947	62	76	8.5	10.2
1948	96	101	8.4	9.0
1949	75	77	10.1	11.6
Average	77	84	9.0	10.4

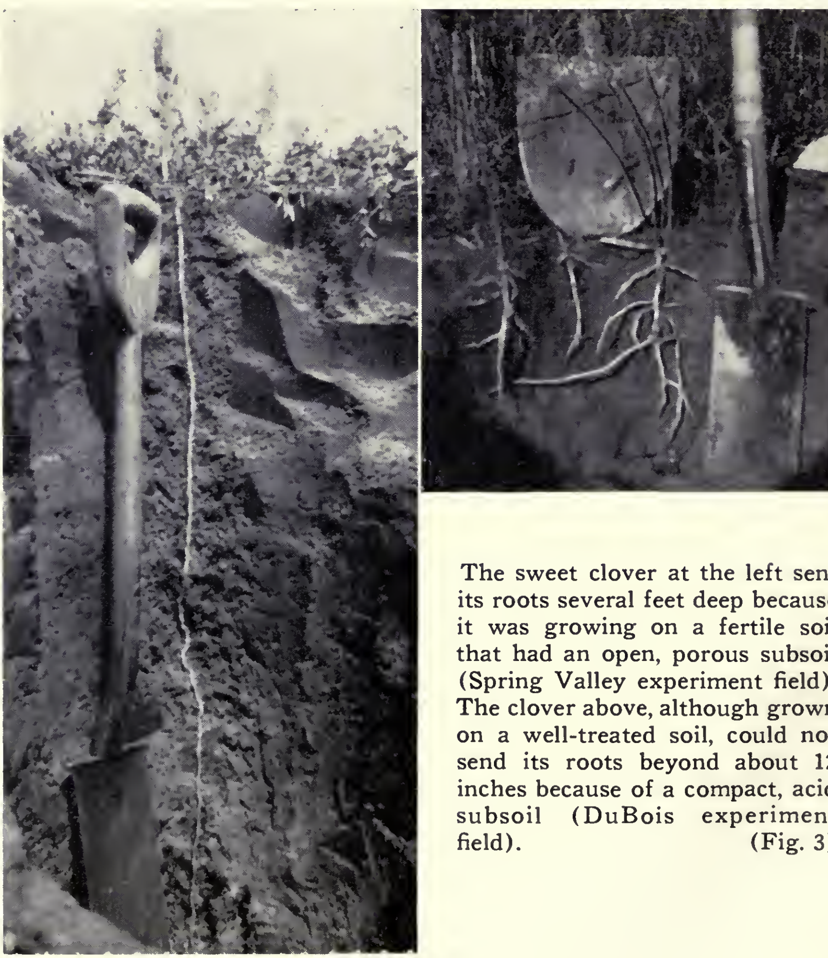
[a] Crop residues, limestone, rock phosphate, muriate of potash.



Differences in subsoils made the difference in the depth to which these alfalfa roots penetrated. Those on the left grew near Enfield on a gray soil with a compact, very acid subsoil. Those in the center grew near Elizabethtown on yellow hill land with a very acid subsoil. The long roots on the right grew near Mansfield on a dark-colored soil with a subsoil only slightly acid. (Fig. 2)

averaged 7 more bushels of grain an acre than corn following soybeans and 78 more pounds of protein in 100 bushels of grain. On untreated land the corn which followed the clover-alfalfa mixture averaged 6 more bushels of corn than the crop which followed soybeans and contained 40 more pounds of protein in 100 bushels of grain. The nitrogen supplied by the roots and straw of the soybeans was enough to increase corn yields somewhat, but was not enough to increase the protein content. The alfalfa-clover mixture was able to do both.

Alfalfa and sweet clover, by nature deep-rooting plants, will



The sweet clover at the left sent its roots several feet deep because it was growing on a fertile soil that had an open, porous subsoil (Spring Valley experiment field). The clover above, although grown on a well-treated soil, could not send its roots beyond about 12 inches because of a compact, acid subsoil (DuBois experiment field). (Fig. 3)

penetrate several feet (Figs. 2 and 3) when grown on land with a favorable subsoil. Where the subsoil is decidedly acid and compact, the main taproots will not usually go below 12 inches. But these two legumes differ considerably in the amount of growth their roots will make and the amount of nitrogen their roots will develop when the crop is grown in shallow soil.

At Elizabethtown and Enfield alfalfa roots that went only 12 inches into the soil were found to weigh as much as those that went beyond 36 inches on the Mansfield field. At Enfield the roots weighed 2,870 pounds an acre, at Elizabethtown 2,910 pounds, and at Mansfield 2,880 pounds (three-year averages). The nitrogen content varied from 55 pounds an acre at Mansfield to 65 pounds at Elizabethtown and 70 at Enfield — the larger amounts, strangely enough, being where the roots were shallow.

Sweet-clover roots, on the other hand, varied considerably in weight and nitrogen content depending on the nature of the soil and whether they went deep or not (Table 7). Deep-rooted sweet clover on dark-colored soil at Carthage averaged, for three years, 1,740 pounds of roots an acre and 83 pounds of nitrogen in the roots. On dark-colored soil at Spring Valley the deep roots averaged, for two years, 3,770 pounds an acre and 176 pounds of nitrogen. But roots of shallow-rooted sweet clover on the DuBois

Table 7. — Dry Matter and Nitrogen in Tops and Roots of Sweet Clover at Time of Plowing Under[a]

Field and sampling date	Depth of roots	Part of plant	Dry matter	Nitrogen
			lb.	*lb.*
Spring Valley	Deep	Tops	290	17
April 5-20		Roots	3 770	176
		Total	4 060	193
DuBois	Shallow	Tops	1 490	52
April 25		Roots	1 080	27
		Total	2 570	79
Carthage, not cut in fall	Deep	Tops	960	46
April 13-18		Roots	1 740	83
		Total	2 700	129
Carthage, cut in early fall	Deep	Tops	340	16
April 13-18		Roots	710	26
		Total	1 050	42

[a] Averages of two years at Spring Valley and three years at Carthage; DuBois data are for one year only.

field, a light-colored soil, produced only 1,080 pounds an acre and only 27 pounds of nitrogen.

Roots of sweet clover and of alfalfa showed a very decided difference in their response to the removal of hay crops. Alfalfa roots remained about the same in bulk even though a hay crop was taken off regularly three times during the season, with the last cutting early in September. For sweet clover, however, the removal of a September cutting on the Carthage field caused the acre-weight of roots to drop from 1,740 pounds to 710, as an average of three years.

Soybeans Take Nitrogen From Soils

A soybean crop contains a large amount of nitrogen, but the greater part is in the beans and is removed from the land with the beans. The part returned to the soil — the straw and roots — is not enough to build up the nitrogen supply. The dry matter and nitrogen in soybeans on the Joliet field were divided in this way (average for five years):

	Dry matter		*Nitrogen*	
	Pounds	*Percent of total*	*Pounds*	*Percent of total*
Beans (24.4 bushels per acre)	1 460	28.1	94	66.3
Tops and roots	3 740	71.9	48	33.7
Total	5 200	100	142	100

Thus two-thirds of the nitrogen in the crop was in the beans, although they contained less than one-third of the dry matter.

That soybeans draw on soil nitrogen can be shown by measuring the nitrate nitrogen (available nitrogen) in the soil during the growing season of a soybean crop. On the Joliet field in 1940 the nitrate nitrogen in the topsoil of the treated plot (residues, limestone, rock phosphate, potash) dropped from 256 pounds an acre at the beginning of the growing season, May 24, down to 20 pounds on July 20, when the soybeans had made their greatest growth. The nitrate nitrogen in the soil at different dates was:

	May 12	*May 24*	*June 5*	*July 20*	*Aug. 24*	*Sept. 27*	*Oct. 13*
				(Pounds per acre)			
No treatment	128	132	140	16	4	14	16
RLrPK treatment	100	256	144	20	6	12	16

Under conditions similar to those on the Joliet field a 25-bushel soybean crop might take up from the soil as much nitrogen (142 pounds) as a 100-bushel corn crop (140 pounds).

Residues of Nonlegume Crops Add Organic Matter But Little Nitrogen

Residues of nonlegume crops are valuable in soil improvement because they add a large bulk of organic matter. The amount of these residues can be very large, especially where the land is treated with limestone, rock phosphate, and muriate of potash (RLrPK).

As an average of several experiment fields for several years, the crops in a four-year rotation (corn, oats, wheat, and soybeans) on treated land returned a total of almost 5½ tons of dry matter an acre and 93 pounds of nitrogen (Table 8). On untreated land the same rotation returned less than 4 tons of dry matter an acre and 60 pounds of nitrogen. In the area of light-colored soils the treated land returned almost 4½ tons of dry matter and 76 pounds of nitrogen from the four crops. On

Table 8. — Amounts of Crop Residues and Nitrogen Left on Land After Harvest[a]

(Pounds per acre)

Residues	General soil class	Untreated land		RLrPK[b] applied	
		Dry matter	Total nitrogen	Dry matter	Total nitrogen
Cornstalks	Dark	1 850	16	3 650	31
	Light	1 120	10	3 660	33
Oat straw	Dark	1 650	7	1 950	8
	Light	360	2	1 330	6
Wheat straw	Dark	1 510	8	2 140	11
	Light	230	1	1 720	9
Soybean straw	Dark	2 680	29	3 200	43
	Light	830	9	2 190	28
Total	Dark	7 690	60	10 940	93
	Light	2 540	22	8 900	76

[a] Averages for four experiment fields for four years, except that the averages for soybeans are based on two fields for five years.

[b] Crop residues, limestone, rock phosphate, muriate of potash.

the untreated soils of this area the average was 1¼ tons of dry matter and 22 pounds of nitrogen.

Cornstalks and straw are relatively low in nitrogen and so do not carry much of this element back to the soil. Analyses at the Illinois Station showed that a ton of wheat straw contained only 10 pounds of nitrogen while a ton of Ladino clover contained 71 pounds (Table 9). A ton of timothy hay contained 20 pounds of nitrogen and a ton of alfalfa hay 58 pounds. These comparisons are typical of the relation between legumes and nonlegumes so far as nitrogen is concerned.

Table 9. — Chemical Composition of Farm Crops in Illinois[a]

Crop	Nitrogen	Protein	Phosphorus	Potassium	Calcium	Magnesium
	lb.	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*
Corn						
Grain, 100 bushels	97.4	609	13.4	24.6	5.0	9.0
Stalks, 4,480 pounds	38.1	238	4.0	66.8	24.2	18.4
Cobs, 1,120 pounds	4.6	29	.4	9.2	1.2	.7
Total	140.1	876	17.8	100.6	30.4	28.1
Oats						
Grain, 50 bushels	31.2	195	4.0	12.8	2.2	3.0
Straw, 1,700 pounds	7.3	46	1.4	47.3	6.3	2.6
Total	38.5	241	5.4	60.1	8.5	5.6
Wheat						
Grain, 25 bushels	21.6	135	3.6	9.3	1.0	2.7
Straw, 2,000 pounds	10.2	64	1.0	16.2	3.6	2.4
Total	31.8	199	4.6	25.5	4.6	5.1
Soybeans						
Beans, 25 bushels	95.4	596	5.3	28.0	3.8	4.2
Straw, 2,840 pounds	31.2	195	1.4	15.0	45.7	26.1
Total	126.6	791	6.7	43.0	49.5	30.3
Hay (2,000 pounds)						
Ladino clover	71.2	445	6.2	44.8	32.2	9.6
Alfalfa	58.0	362	3.6	38.6	36.0	8.6
Birdsfoot trefoil	55.0	344	4.0	33.4	32.6	11.6
Red clover	55.2	345	3.4	39.6	38.2	9.2
Soybean	52.0	325	3.0	18.2	28.0	17.8
Lespedeza	40.4	252	2.9	18.9	17.0	5.7
Bromegrass	29.8	186	3.4	44.3	8.0	3.0
Kentucky bluegrass	29.4	184	3.8	32.8	6.2	4.0
Timothy	19.6	122	3.0	31.4	5.6	3.6
Redtop	21.2	132	3.4	31.8	8.4	4.4
Orchard grass	19.4	121	3.6	38.0	5.4	4.2
Alta fescue	29.0	181	3.6	36.0	5.5	4.1

[a] Averages of 50 analyses except for birdsfoot trefoil, which had 20 and Alta fescue which had 10. Stalks, cobs, and straw represent the amounts which accompany the indicated yield.

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